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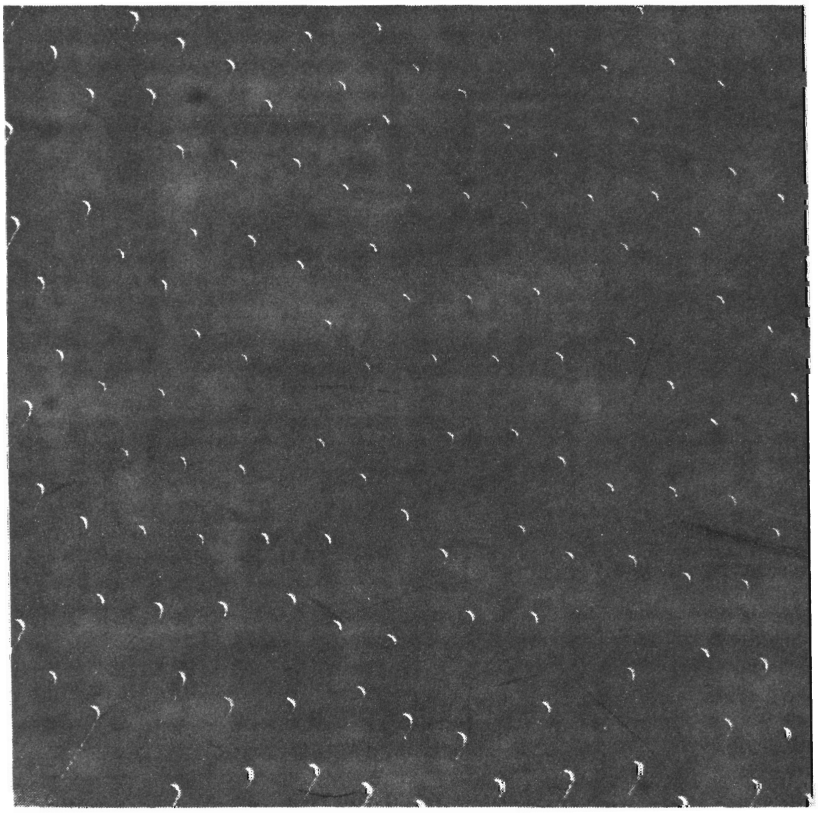
Technical Guide

Principles of the Compact Disc System



Compact disc magnified 4,000X

Technics

MATSUSHITA ELECTRIC INDUSTRIAL CO., LTD.
DISCPLAYER DIVISION, SERVICE GROUP.

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Today, our music sources consist of FM/AM tuners, recorded discs and tapes. Recently, a new source has been added based on PCM (pulse code modulation) technology. The new source that is attracting attention is Digital Audio. This tchnical guide will cover the general principles of digital audio dealing with the new compact disc format.

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1. Analog vs Digtal

The ultimate goal of audio reproduction is to reproduce a signal that has the same sonic qurlity as that of the original performance.

Currently, in analog systems, Technics has made vast improvements in audio reproduction with the design of our new class A, computer driven amplifiers, linear feedback circuits, honeycomb speakers, etc. However, we are approaching physical limitations in improving performance at a reasonable cost. In the audio amplification process, the analog signal is subject to noise and distortion in the transmission line that will also appear in the output signal. (Fig. 1a).

By using digital techniques, we can reduce or eliminate these transmission line effects and produce an output signal that is almost a perfect reproduction of the original signal. (Fig. 1b)

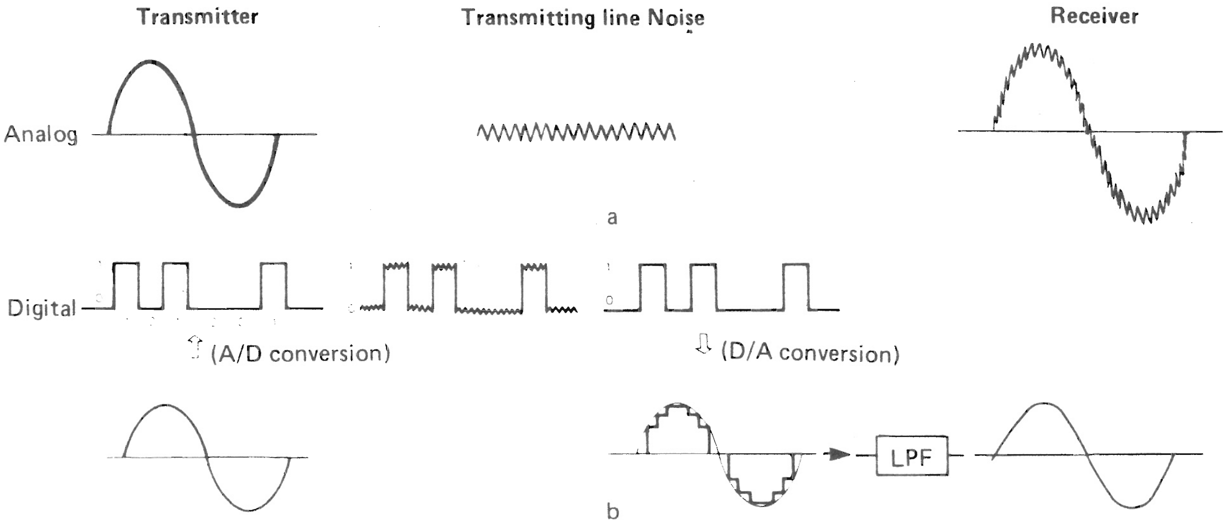


Fig. 1 Analog vs digital reproduction

2. Digital systems

In recent years, various committees have convened to discuss the standardization of both hardware and software for the new digital audio systems. Chart 1 outlines the systems that have been accepted and are being manufactured. Table 1 compares some features of the two "Playback Only" systems - Compact Disc (CD) and Audeo High Density (AHD).

DIGITAL AUDIO SYSTEMS

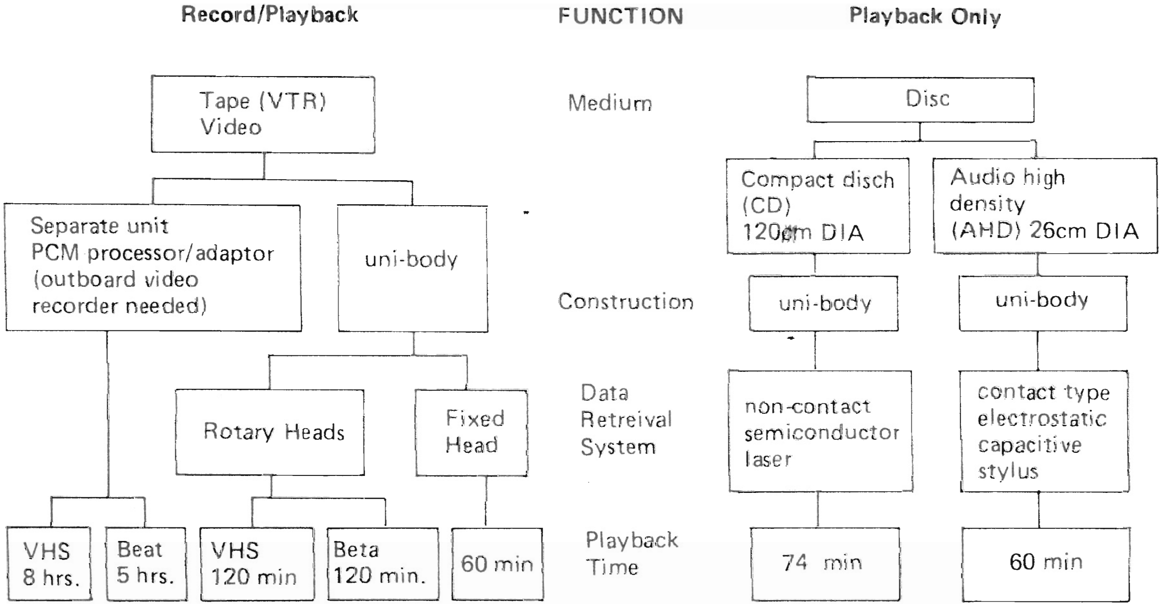


Chart 1 Comparison of digital audio systems

Name of system	Compact Disc (CD)	Audio high density (AHD)
Propsed by	Philips, Holland	Victor, Japan
Disc diameter	12 cm	26 cm
Channels	Stereo 2ch or 4ch	4ch (3ch & color still image)
Play time	74 min. (2ch)/side	60 min./side
Disc Speed	200~500 r.p.m. Constant Linear velocity	900 r.p.m. Constant angvlar velocity

Table 1 Comparison of CD and AHD

3. Compact Disc Features

1) **Superior Sound Quality**
- To maintain master recorder quality, the information on the disc is recorded with 16-Bit linear quantization.
- To improve recording density (playback time), eight to fourteen bit modulation (EFM) is used. This allows 2 channel playback for 74 minutes.
- To realize stable data reproduction a special error correcting code called the Cross Interleave Reed-Solomon code (CIRC) is used.

2) **Virtually Indestructable**
- The non-contact laser playback system allows repeated use with no degradation in quality.
- The plastic coating over the signal information protects it against scratches, dirt and fingerprints.

3) **Small Size**
The small size allows for easy, compact storage.

4) **Random Access**
The control information recorded on the disc allows random access and character display such as names of tunes, artists etc.

4. PCM Features

Using a PCM system for Audio reproduction has certain advantages.

1. Not affected by noise of the recording medium. The digital system only has to detect two types of signals (0's and 1's). This is much easier than trying to detect the infinite number of possible amplitudes and frequencies of an analog signal.
2. Eliminates effects of uneven rotation of the playback equipment due to a quartz controlled reading clock.
3. Able to Correct Errors.
   Besides including the recorded signal, the digital data has error correction information. This allows the digital circuit to calculate what the information should be if the music signal can not be rear properly because the disc surface is marred by dirt or scratches.

5. PCM Process for CD

The PCM process has several fundamental steps regardless of whether the application is satellite data transmission or simply audio reproduction. A general description is given of the recording and playback procedures followed by an explanation of each step.

5-1. General description (Fig. 2.)

5-2. Recording

An analog signal is "sampled" at a specified frequency. The amplitude of each sample is "quantized" and the value is converted into a binary number. The binary numbers are encoded into a pulse train along with sync, control and error correction information. The digital pulse train is then recorded onto a tape or disc by contact video heads, electrostatic capacitive stylus or non-contact laser beam.

5-3. Playback

Playback is the reverse of the recording process. The digital information on the tape or disc is retrieved by video heads, capacitive stylus or a lasere beam. The digital pulse train is decoded, quantized converted from digital to analog. The waveform then passes through a low pass filter and the original signal is restored at the output.

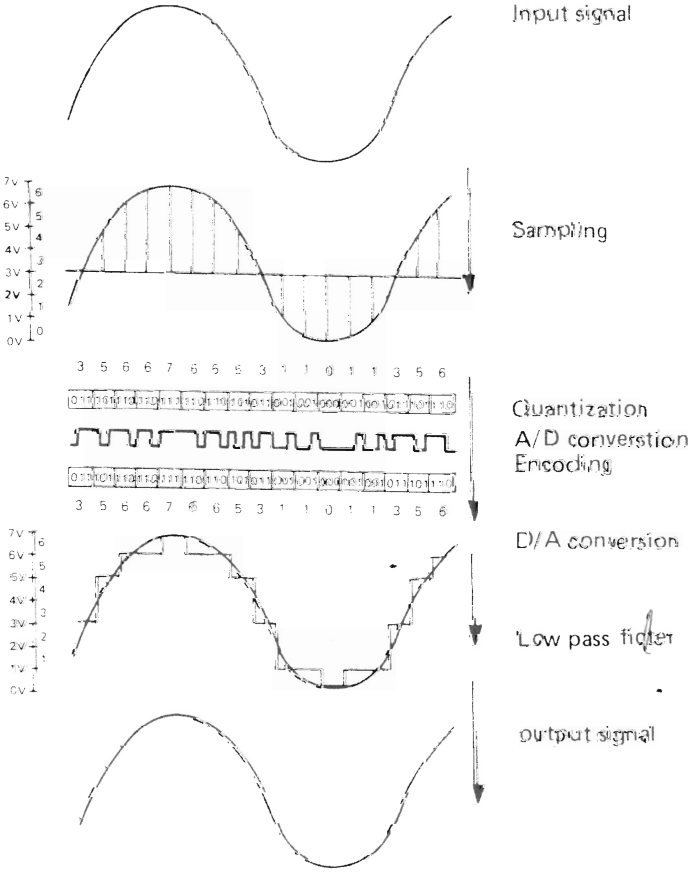


Fig. 2 PCM process

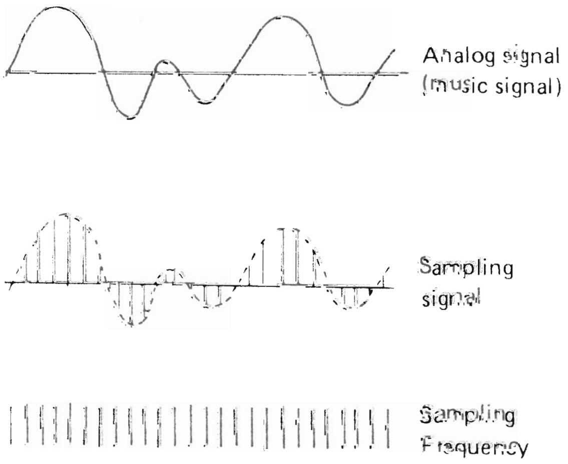
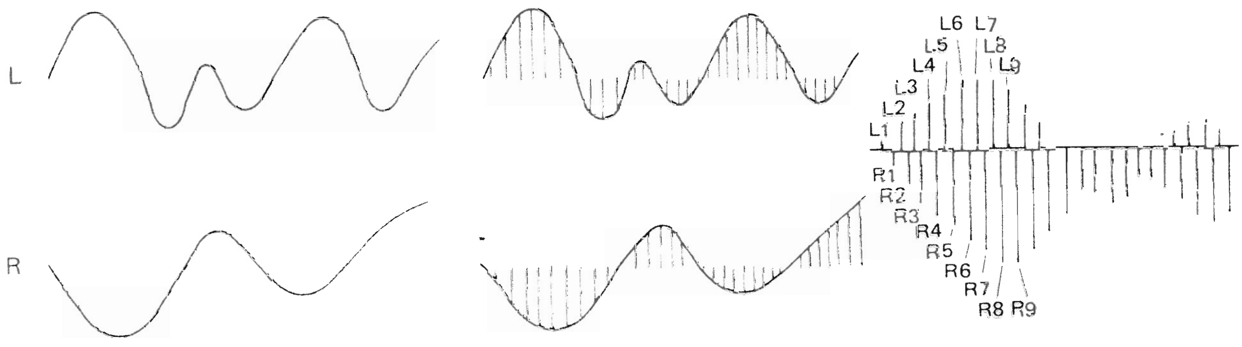


Fig. 3 Sampling

5-4. Sapmling

To convert an analog signal into digital form, we must take measurements at regular intervals along the waveform. This is called sampling and the rate of the intervals is called the sampling frequency or rate (Fig. 3). The more samples taken that is, (the higher the sampling frequency) the more accurate the waveform can be represented by the samples.

For audio purposes, the highest frequency that the system must record is 20kHz. It has been proven that the sampling frequency required for accurate reproduction must be at least 2X the highest frequency to be recorded. That is, for a maximum frequency of 20kHz, the sampling frequency must be at least 40kHz, This is referred to as the sampling theorum. For compact disc systems we use 44.1kHz to allow for some circuit tolerances. Sampling alternates between left and right channels to form a composite signal waveform as shown in Fig. 4.



Anrlog signal Sampled signrl- Composite singal

Fig. 4 Composite audio signal

5-5. Quatization and A-D Conversion

After the analog waveform is sampled, the amplitude of each sample is converted into a binary number. This is called quantization and analog to digital (A-D) conversion. Each binary number is composed of 16 bits. This means that for each amplitude sampled, there are 65,536 different values possible. Fig. 5 uses a 4 bit number as an example.

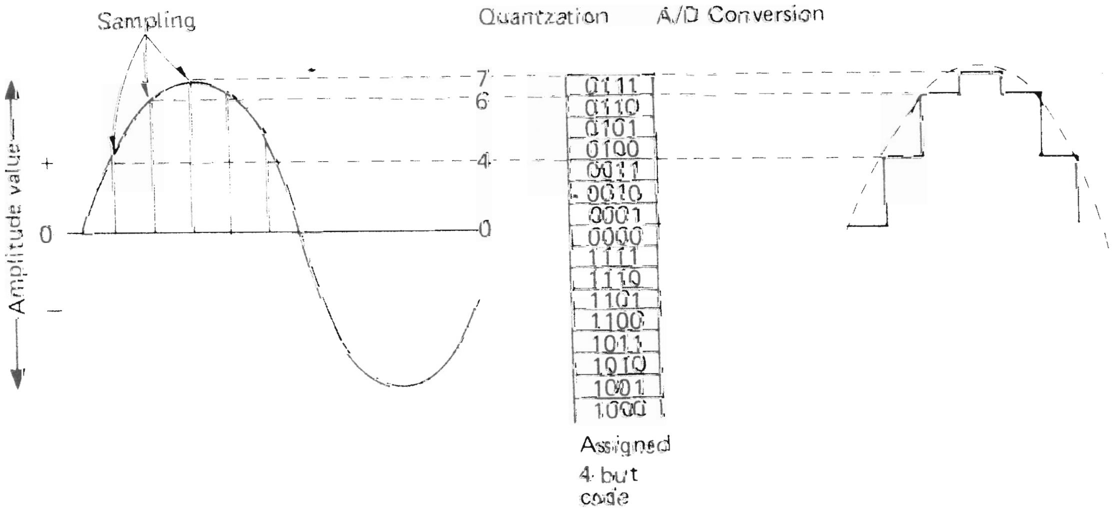


Fig. 5 Quantization and A-D conversion

The analog signal contains both positive and negative quantities. To express the negative quantities digitally, computers use offset binary codes. However, some inconveniences arise. To reduce the number of arithmetic operations and memory size, a 2's complement code is used.

To change the offset code to 2's complement, invert the number and add 1. See Table 2.

Natural binary code		Offset binary code			2's complement code
7	1 1 1	+3		1 1 1	0 0 1
6	1 1 0	+2		1 1 0	0 1 0
5	1 0 1	+1		1 0 1	0 1 1
4	1 0 0	0		1 0 0	1 0 0
3	0 1 1	−1	(Offset)	0 1 1	1 0 1
2	0 1 0	−2		0 1 0	1 1 0
1	0 0 1	−3		0 0 1	1 1 1
0	0 0 0	−4		0 0 0	0 0 0

Table 2 2's complement code

To understand A-D conversion it is much simpler to explain D-A conversion. (Fig. 6)

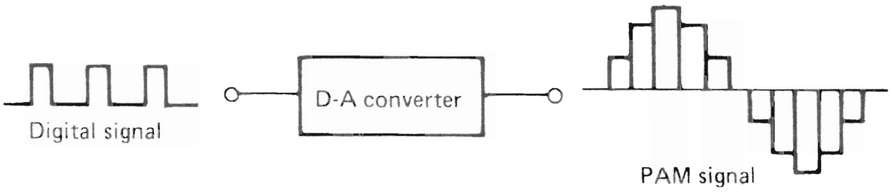
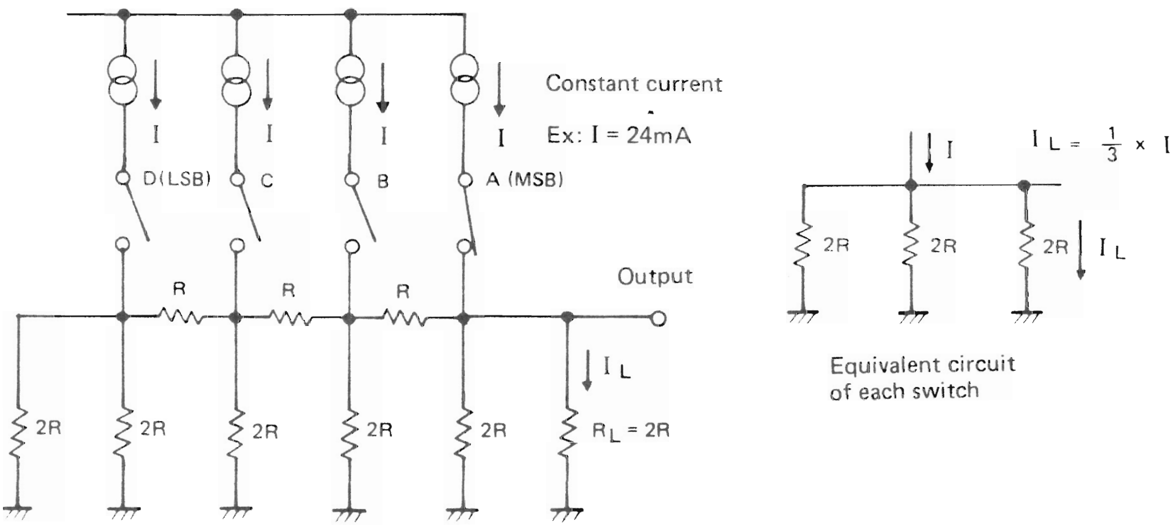


Fig. 6 D-A conversion

The following is an example of D-A conversion using a 4 bit word.
When the digital pulse train is converted to a digital word, switches A through D correspond to each bit. A "1" is represented by a closed switch and A "0" by an open switch. The sum of the currents of the closed switches flows through R/L and a corresponding voltage is developed at the output. These voltages are used to construct the pulse amplitude modulation (PAM) signal.

An example of one type of D-A converter used is the ladder type illustrated in fig. 7.



Equivalent circuit of each switch

Fig. 7 Ladder type D-A converter

Tow types of resistors (R and 2R) are used. If $I = 24$ mA the following conditions exist.

Digital quantity				Current flowing to each switch				Analog quantity (total)
A	B	C	D	A	B	C	D	
1	1	1	1	8 +	4 +	2 +	1	= 15mA
1	1	1	0	8 +	4 +	2 +	0	= 14mA
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	
1	0	1	0	8 +	0 +	2 +	0	= 10mA
1	0	0	1	8 +	0 +	0 +	1	= 9mA
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	
0	0	0	1	0 +	0 +	0 +	1	= 1mA
0	0	0	0	0 +	0 +	0 +	0	= 0mA

A is ON, then $I_L = \frac{1}{3}I = 8mA$

B is ON, then $I_L = \frac{1}{3}I \times \frac{1}{2} = \frac{1}{6}I = 4mA$

C is ON, then $I_L = \frac{1}{3}I \times \frac{1}{4} = \frac{1}{12}I = 2mA$

D is ON, then $I_L = \frac{1}{3}I \times \frac{1}{8} = \frac{1}{24}I = 1mA$

Table 3 Digital quanity vs current

The A-D conversion is more comlex but , in principle, it is the reverse of D-A conversion.

Quantization Noise

Even though a 40kHz sampling frequency will accurately reproduce 20kHz for our ears, there is still some error. Our sampling has only 65,536 possibilities whereas the analog signal has an infinite number of possible amplitudes. This error is referred to as quantization error. (Fig. 6).

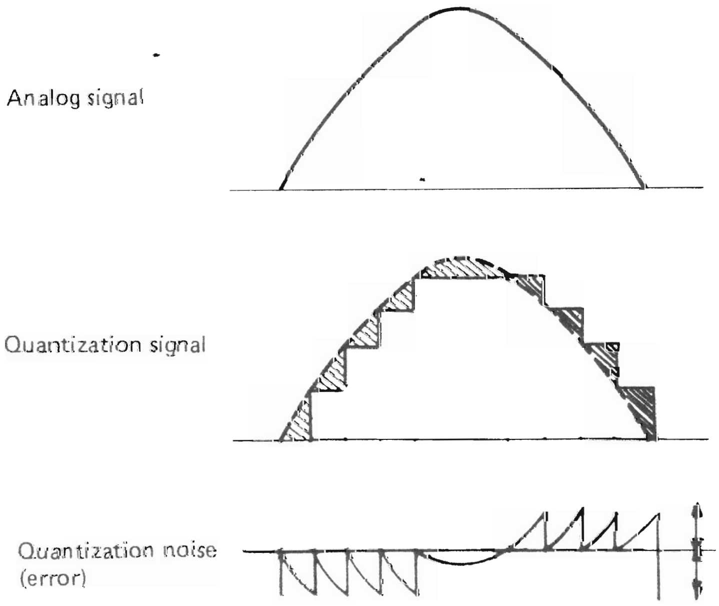


Fig. 8 Quantization noise

Dynamic Range

The quantization noise level can be predicted. The equation to calculate the theoretical maximum signal to noise ratio is

$$\frac{S}{N} = 6n + 2 \qquad n = \text{number of bits} \qquad [dB]$$

As you can see, the ratio is determined largely by the number of bits used to represent each quantized sample.

In 14 bit quantization the maximum S/N = 86dB
In 16 bit quantization teh maximum S/N = 98dB

5-6. Encoding

In addition to the digital data from quantization, other information such as syncronizing, control and error correction data is also included in the pulse train. The actual data encoding system is called EFM. (Eight to fourteen bit modulation)

The digital pulse train is encoded onto the disc using an EFM system.

Why is EFM needed?

1) **To increase recording density (playback time).**
If a conventional digital signal is used, a high frequency inversion of 1's and 0's is necessary. This requires smaller pits which are difficult to read because of cutting or molding variations and optical pick-up tolerances.

2) **To maintain tracking.**
If a series of 1's or 0's continues for a long time, the tracking servo cannot lock and follow the proper track.

3) **To simplify the data processing circuits.**

Since the diameter of the laser beam at the pit surface is 1μm, pits smaller than .9μm cannot be read. Also, to reduce the high frequency inversion, there must be at least two "0"s between each 1. This minimum requirement satisfies item 1.

To satisfy item 2, there must be no more than 10 "0"s in succesion to maintain proper tracking.

5-7. The EFM Mechanism

The ~~will~~ word "Modulation" may be a little misleading. When the EFM mechanism is examined. Perhaps the word "conversion" woull be more accupate.

EFM Mechanism

Each 16 bit word is divided into two 8 bit words. Each 8 bit word is converted into a 14 bit word plus a 3 bit junction word. This is encoded onto the disc.

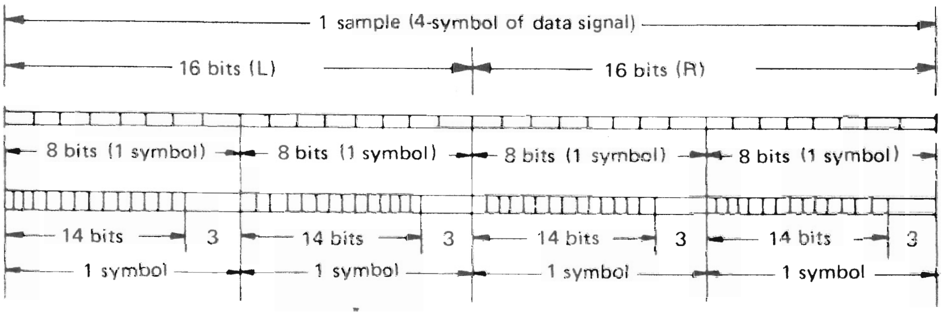


Fig. 9 8 to 14 bit conversion

The reason that the 8 bit word must be changed to a 14 bit word is because there must be at least two ~~"0s"~~ and ~~no~~ less than 10 "0's" between each "1". Of the 256 (2^8) possible combinations of an 8 bit word, only about 100 will satisfy this requirement.

With a 14 bit word, there are 16,384 (2^{14}) possible combinations, about 276 of which can be used. This is more than enough for the 256 different combinations we need.

The 8 bit data is, therefore, converted into more usable 14 bit data.

In addition to the new 14 bit data, a 3 bit junction word is added to separate adjacent data. This is needed to assure that the requirements of having 2-10 "0's" between each "1" is satisfied when joining two 14 bit words.

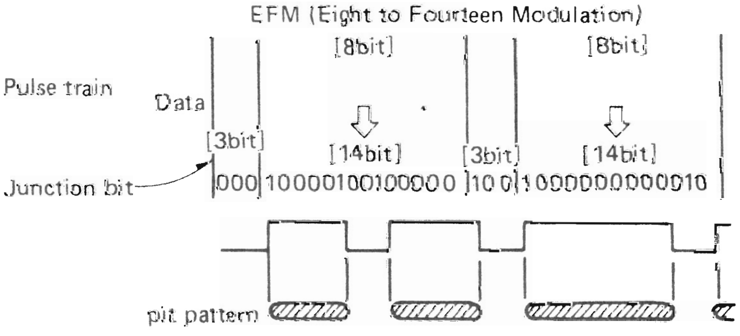


Fig. 10 EFM vs pit pattern

Fig. 10 illustrates the relationship between the EFM signal and the disc pit pattern. You will notice that the data changes from 0 to 1 only at the edges of a pit.

5-8. Pulse Train Format

The format of the pulse train encoded onto the disc is organized as a series of frames. The contents of a frame is outlined in Fig. 11.

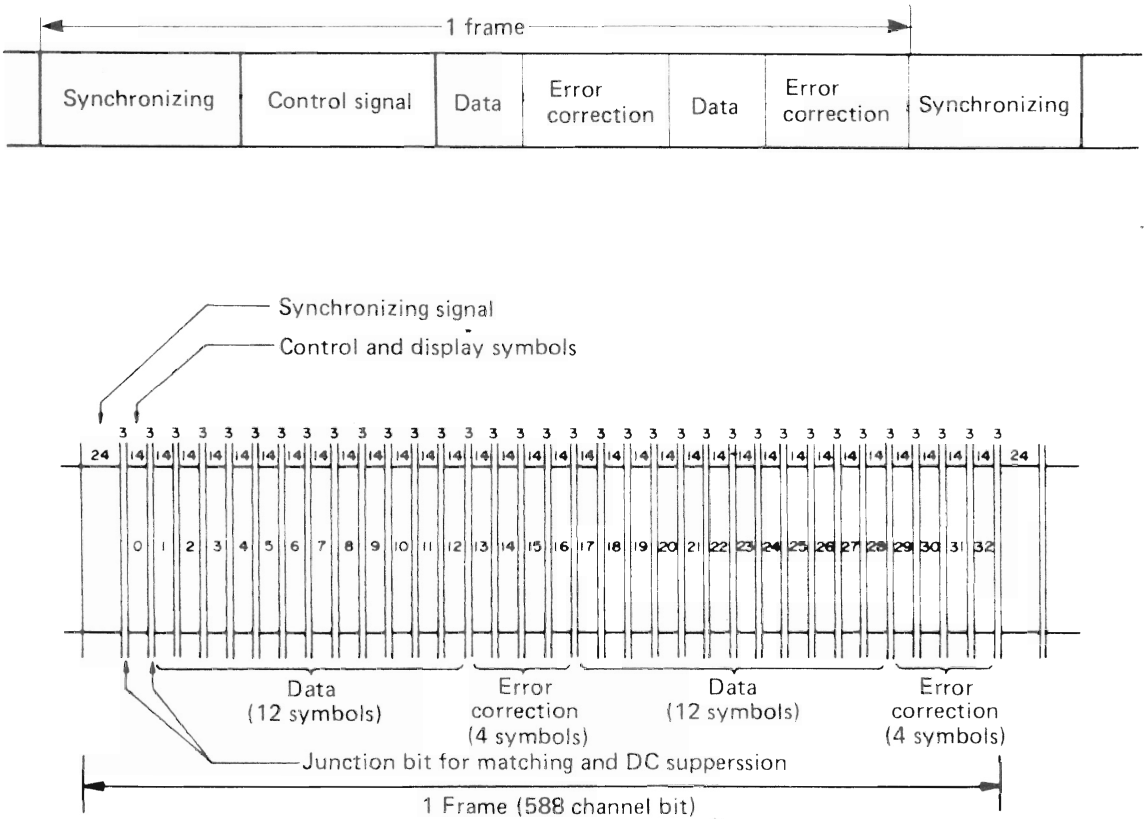


Fig. 11 Contents of 1 frame 24 + 3x34 + 14X33

Syncronizing Signal : This 24 bit word is used to keep the disc rotating at a constant reading speed of 1.3m/sec (CLV) the sync signal frequency is 7.35 kHz.

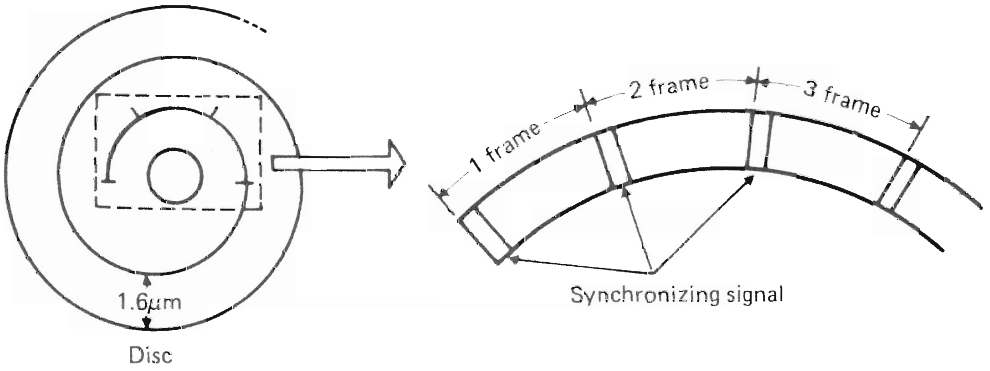


Fig. 12 SYNC signal location

Control Signal

This 14 bit information is used for random access and display information such as track number, lapse of time, etc.

The control information has 8 channels allocated but only 2 are used.

frame	Sub-code channel No.	P	Q	R	S	T	U	V	W
	0	Synchronizing signal							
	1	Synchronizing signal							
	2								
	⋮			Not used					
	96								
	97								

1.75 sec. (13.3ms)

Fig. 13 Control signal sub channels

The P channel is used to discriminate between a music signal and a blank.

The Q channel includes the table of contents (TOC), program track and lead out track for use in the display, and random access control.

Since the disc information is divided into the table of contents (TOC) and program sections, the control signal also has two formats.

Fig. 14 shows the arrangement of the lead-in track and the Program/Lead-out track

Lead-in track

Music No.	Point (Tune No.)	Lapse of time ⟨tune⟩ (min. sec. frame)	Zero	Lapse of time ⟨total⟩ (min. sec. frame)

Program track and lead-out track

Control emphasis present or absents	Discrimination No.	Music No.	Music No. of index	Lapse of time ⟨tune⟩ (min. sec. frame)	Zero	Lapse of time ⟨total⟩ (min. sec. frame)

Fig. 14 Contents of P & Q sub channels

The complete control signal information is the accumulation of the data in a series of frames. For instance, on a certain disc the TOC is contained in the first 98 frames.

After reading these 97 frames the TOC is displayed.

- Fluorescent display tube

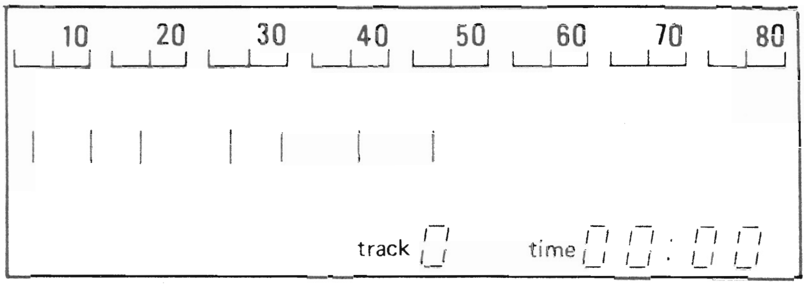


Fig. 15 TOC displayed

The program control signal is also read as a series of frames, however,the information is constantly updated to give the correct track number, lapsed time, etc. This allows for precise location for random access functions.

Data

The data is the actual audio signal that has been sampled, quantized and converted to a digital word.

There are two blocks of data within each frame. Each block contains 12 symbols (6 left channel and 6 right channel audio samples. See Fig. 16.)

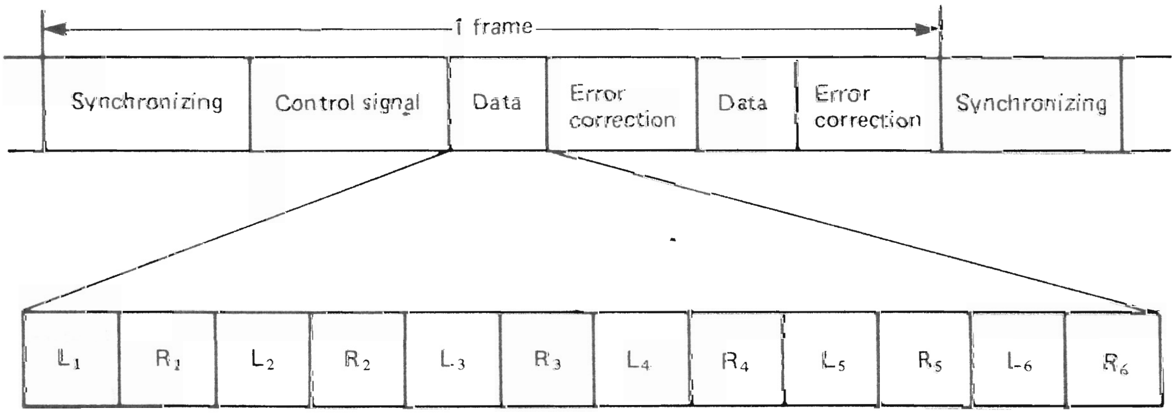


Fig. 16 Data signal

14 bit + 3bit (junction)

A symblo, as explained before, is a 14 bit word plus a 3 bit junction word.

The interleave system, enables more errors to be corrected. The actual corrections are then done by the cross interceave reed solomon code (CIRC)

Error Correction

Due to disc manufacturing tolerances and surface scratches, dust and dirt, it is necessary to include some error correction so that the sound may be reproduced undisturbed for corrections in the compact disc system two steps are used.

A) Interleave/Deinterleave

When the EFM signal is recorded onto the disc it is arranged out of sequence using a specific code (interleave) When the signal is played back it is rearranged back into the correct sequence (de-interleave)

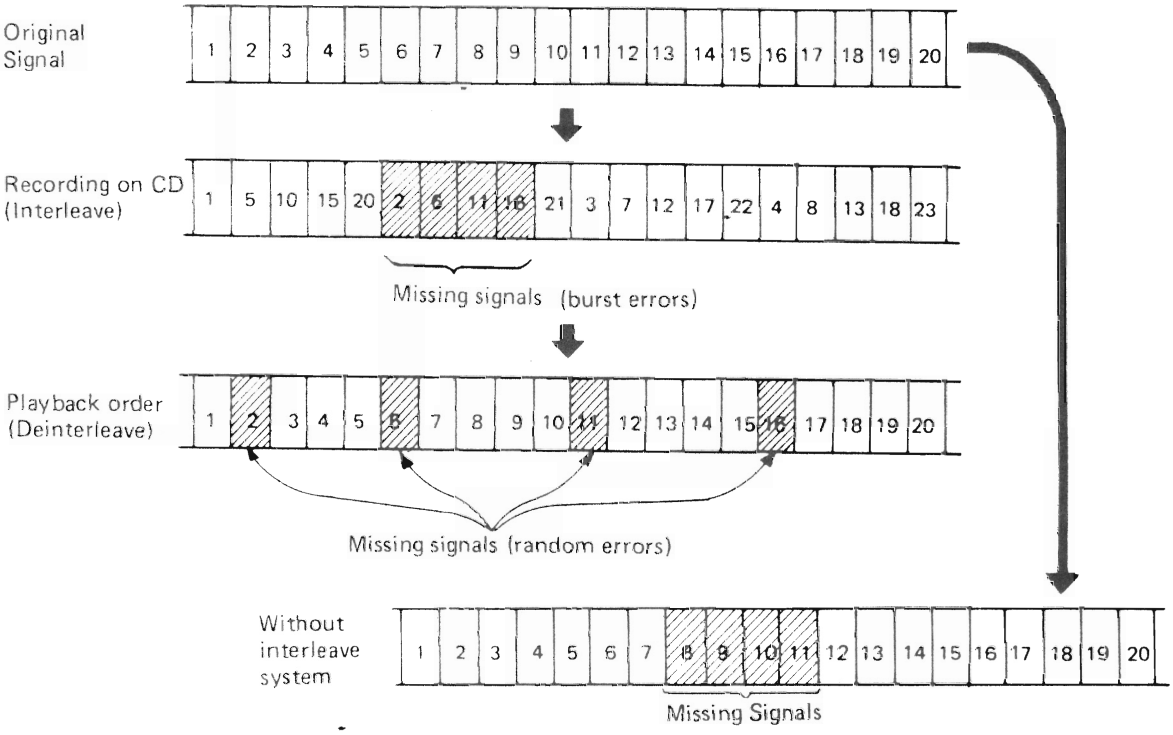


Fig. 17 **Interleave/deinterleave system**

This system is useful when there is dirt or dust on the disc blocking a group of signals. When the group is played back after deinterleave, the errors become random and are easily corrected by the error correction information recorded on the disc.

The parity information is not necessary if we can guarantee that all of the recorded data is read accurately.

B) **Cross Interleave Reed-Solomon Code (CIRC)**

The error correction information on the disc consists of parity or redundant signals that will be used in arithmetic operations to fill-in any random errors.

Table 5 liest the number of sunny days in several cities. this represents the recorded data. At the end of each row and column is a total. These totals represent the parity bits or redundant information. It is not necessary that all of the data be read accurately. If some data is missing, it can be calculated by arithmetic manipulation of the remaining data.

Day / City	Sun.	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Total
Paris	3	1	1	4	3	2	2	16
London	1	1	2	2	4	3	2	14
Bon	2	2	1	2	3	2	3	15
Rome	3	2	1	2	2	1	2	13
Tokyo	2	1	2	2	2	2	2	13
Total	11	7	7	12	13	10	11	71

Table 5 Example of parity information

The system used in the compact disc is very complex and is called The Cross Interleave Reed-Solomon Code (CIRC).

6. Disc Mastering

The disc mastering and manufacturing Processes must be done in special "clean rooms". In these rooms the size and amount of dust particles is strictly controled to ensure maximum quality.

- A glass plate bage is (cleaned and polishe)
- A phot resistive coating is applied.
- The digital pulse train modulates the laser beam.
- The coating is devloped and ametale is deposet. The exposed part is removed.
- A nickle master is made.
- A mother is made from the master.
- A stamper is made from the mother.
- The disc is made from the stamper.
- The disc surface is coated with a layer of reflective aluminum.
- A protective coating is applied to protect the signal surface.
- The label is applied.

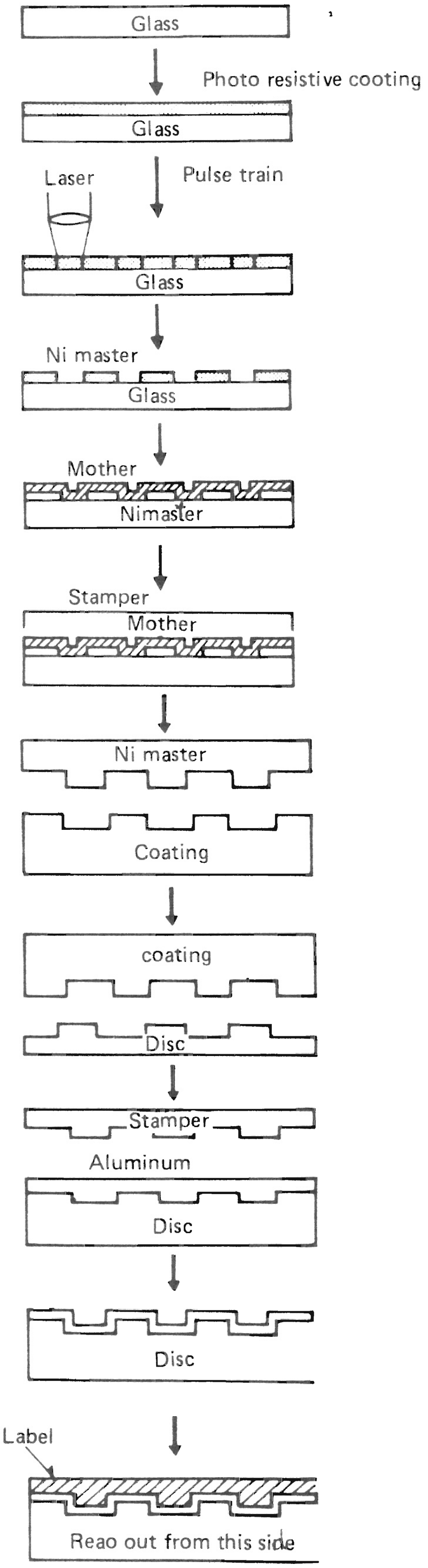


Fig. 19 Disc mastering process

7. Disc Structure and Specifications

As Seen from the Mastering Process

The digital signal is recorded as pits on the glass plate surface but as viewed from the playback laser they are projections. (By convention they are still called pits.)

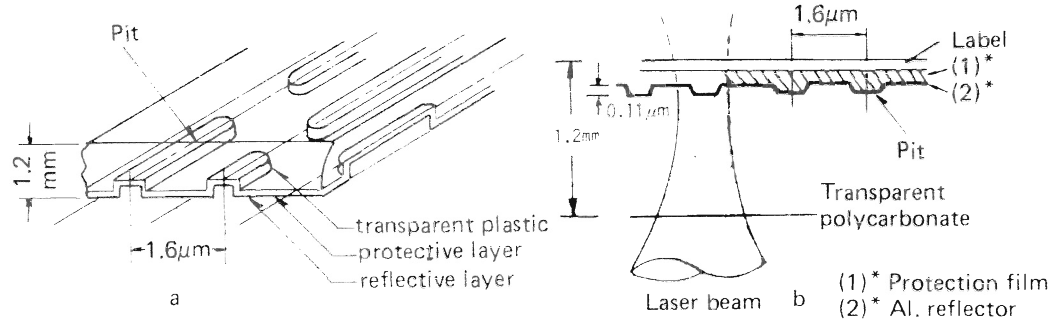


Fig. 20 Disc cross section

The pits are 0.5μm wide, 0.9 – 3.3μm long and 0.11μm deep. The distance between each track (track pitch) is 1.6μm. An average disc may have as many as 20,000 tracks with about 6 ~ 7 billion pits.

Compared to a 30cm LP disc, there are approximately 1,000 grooves, with an average groove equal to 100μm in width.

The aluminum surface of the disc is protected by a polycarbonate layer with a refractive index of 1.5. This is used as part of the playback optical system to focus the beam on the pits.

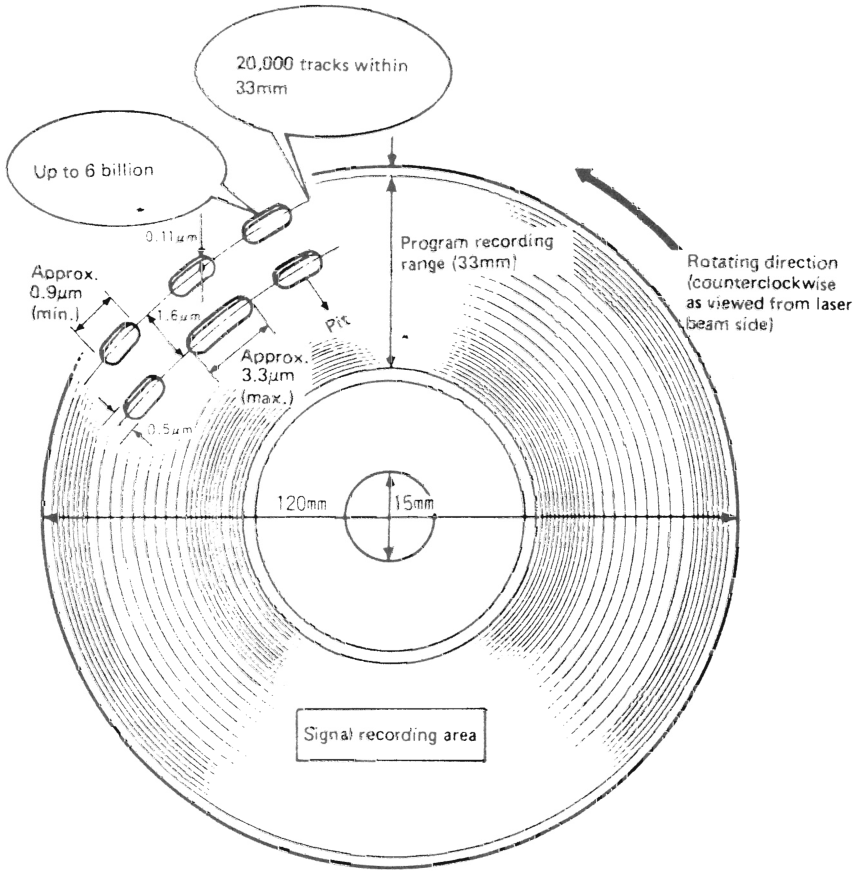

20,000 tracks within 33mm
Up to 6 billion
0.11μm
Approx. 0.9μm (min.)
1.6μm
Pit
Approx. 3.3μm (max.)
0.5μm
Program recording range (33mm)
Rotating direction (counterclockwise as viewed from laser beam side)
120mm
15mm
Signal recording area

Fig. 21 Compact disc

A aynopsis of the disc parametens is given in table.

Paramentr		Compact disc
Propsed by		Philips, Holland
Basic system		Non-contact, optical (for audio)
Disc specification	Disc diameter	120mm
	Thickness	1.2mm
	Hole diameter	15mm
	Recording area	ϕ46 – ϕ116
	Rotating direction (from reading side)	Counterclockwise
	Track pitch	16μm
	Pit size	0.87 ~ 3.2μm
	Relative speed	1.2 – 1.4m/s
	Rotating speed	500 ~ 220 r.p.m.
Audio specification	Number of channels	2 (4)
	Frequency characteristics	20Hz ~ 20kHz
	Dynamic range	greater than 90dB
	Distortion factor	less than 0.01%
	Wow & flutter	quartz accuracy
	Play time	max. 74 minutes (37)

Table 4 Disc specifications

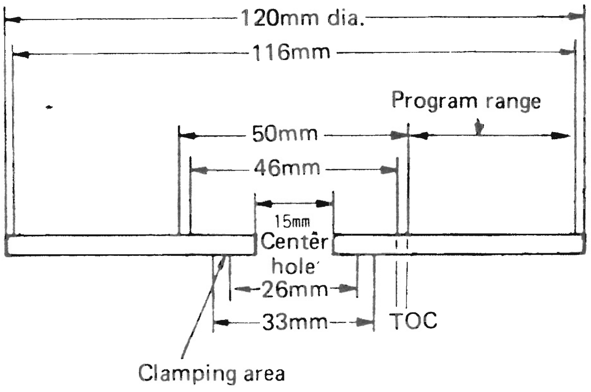


Fig. 22 Disc dimensions

The information on the disc is arranged in two sections.

Lead-in Track

The initial part of the disc contains program information, such as the track number and times of tunes. This is called the "Table of Contents" (TOC). Reading the TOC eliminates the need to scan the entire disc and allows for random access and display information.

The second section of the disc is the program and lead-out area.

8. Compact Disc Player

The block diagram shows two basic sections of the player. The optical pick-up section is responsible for maintaining proper data read out. The signal processing section is responsible for converting the digital signal from the pick-up back into an analog signal for listening.

Starting with the optical pick-up or data recovery section the following is a breakdown of the functions of each optical component from the laser diode to the photo detector.

8-1. Black Diagram

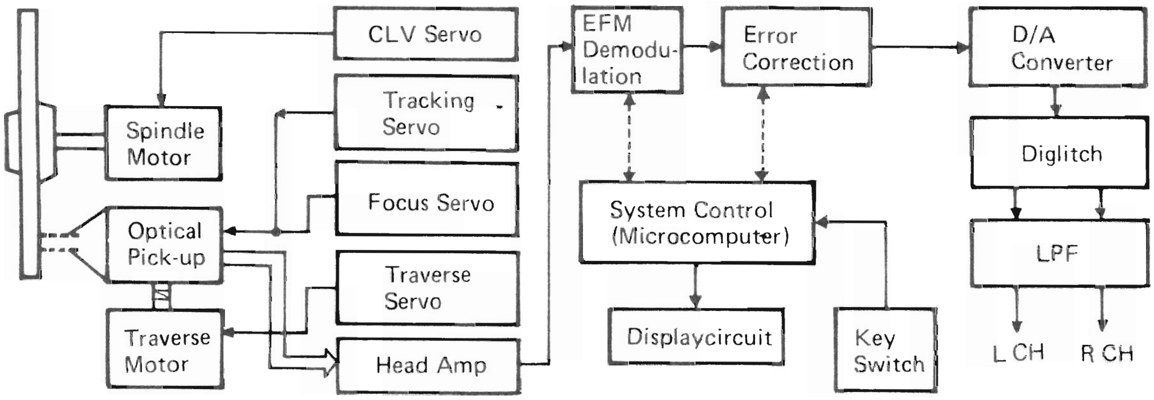


Fig. 23 Block diagram of CD player

The major blocks of the CD player system are as follows:

A) **Optical Pick-up and Servos**

The optical pick-up deck is responsible for retrieving the data from the disc. To do this, 4 servo circuits are needed.

1) Focus servo maintains precise focusing on the pits and compensates for warped discs.
2) Tracking servo allows the focus beam to read the spiral track and compensates for disc eccentricity.
3) Traverse servo allows the focus lens to read the entire disc and is used for FF, REV and high-speed search.
4) CLV servo maintains the proper spindle motor speed.

B) **Signal Processing**

1) Head Amp	: Amplifies the RF signal from the photo detector.
2) EFM Demodulation	: 14 bit code is converted back to 8-bit.
3) Error Correction	: The signals are de-interleaved to the original order. Errors are detected and corrected.
4) D-A Converter	: The digital signal is converted to an analog signal.
5) Deglitch	: The composite left and right signal is separated to two channels.
6) L.P.F.	: The high frequency component is removed and limited from 20-20kHz.

The signal processing explanation will be covered in the circuit descriptions technical guide Vol. 1.

8-2. Optical pick-up

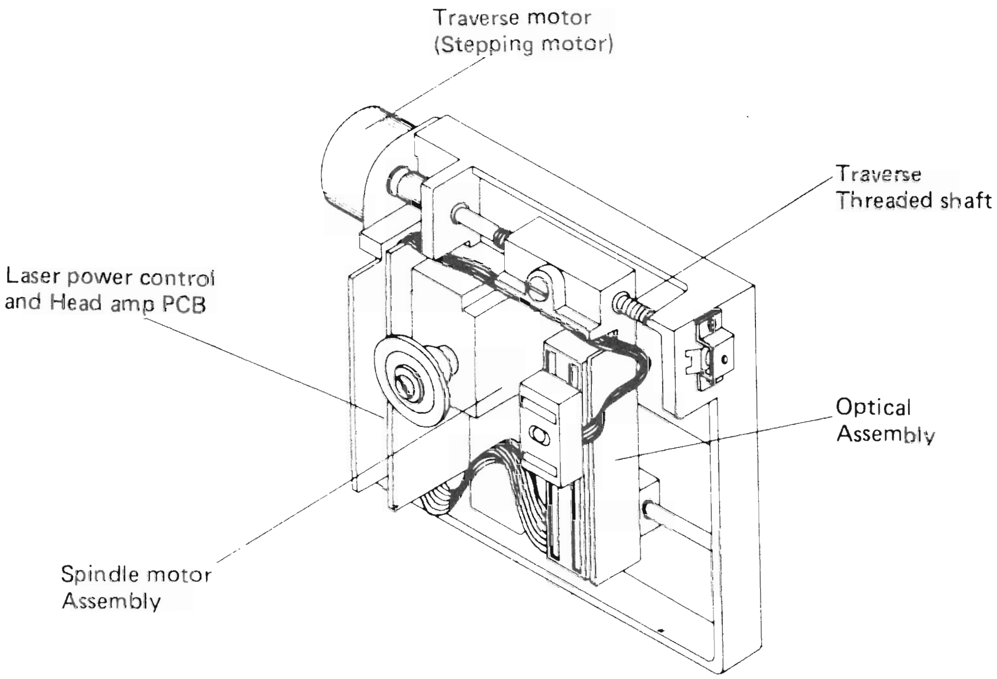


Fig. 24 Optical pick-up deck

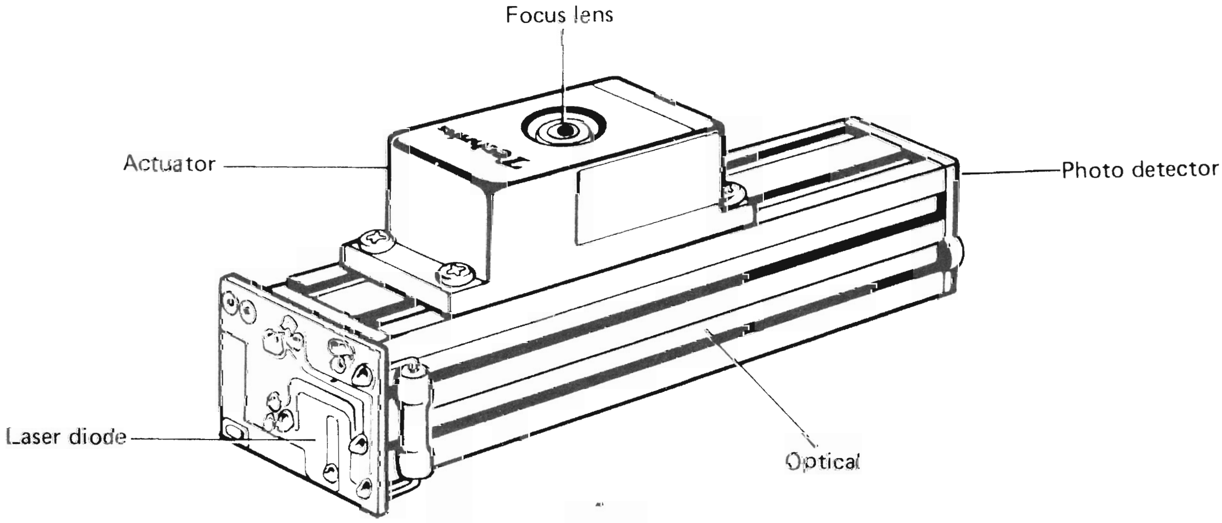


Fig. 25 Optical assembly

Laser Pickup

Laser diode : 8100A (= 0.81um)
Collimater lens : Lens to make laser beam parallel.
Grating : 1 beam is divided into 3 beams.
Beam splitter : Prism that separates the incidental beam and the reflected beam.
1/4 wave plate : Changes the plane of polarization by 90°.
Focus lens : Lens to focus laser beam on pit surface.
Detector lens : Lens to focus the beam on the photo detector.
Photo detector : Converts the light beam modulation into an electrical signal.

8-3.Description of Optical Playback System

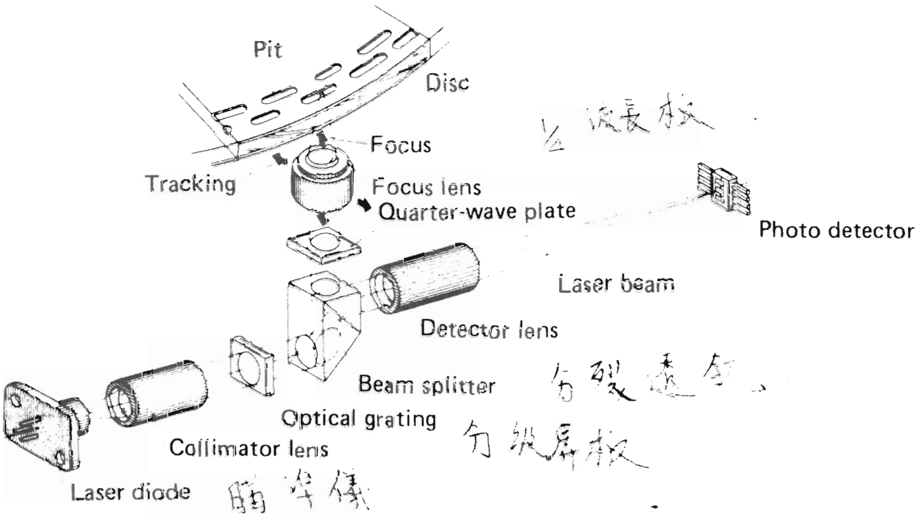


Fig. 26 Optical system

The semi-conductor laser diode emits an invisoble infrared beam at a frequency of 0.81μm. The beam first passes throught a collimator lens which changes the light into paralled beams; and a grating lens which converts the light into multiple beams. The center beam will be used to read the digital information from the disc. The two adjacent beams will be used for tracking. The beam splitter separates the incidental light from the reflected light and the 1/4 λ plate changes the plane of polorization of the reflected light by 90°.

The focus lens converges the light onto the highly reflective surface of the disc and is capable of reading a track with pits only 0.5μm wide, 0.1μm deep and approx. 1 to 3μm long at a track pitch of 1.6μm.

The light reflected from the disc goes back through the focus lens and again through the 1/4 λ plate. After changing the polarization another 90°, the beam is now 180° out of phase from when it first emerged from the beam splitter. The beam splitter is designed to reflect this 180° phase-shifted beam through the detector lens, where the 3 beams are focused onto a photo detector. The photo detector converts the optical digital signal, from the center beam, into an electrical digital signal, which is then processed by subsequent circuits into an audio analog signal.

The two adjacent beams are converted, by the photo detector, into electrical signals that feed back to the servo circuits to maintain accurate tracking.

8-4. Actuator Assembly

Fig. 27 illustrates the structure of the actuator. Two sets of drive coils (A & B) are positioned 90° to each other. The twin parallel damper supports the assembly so the focus lens can move in any direction.

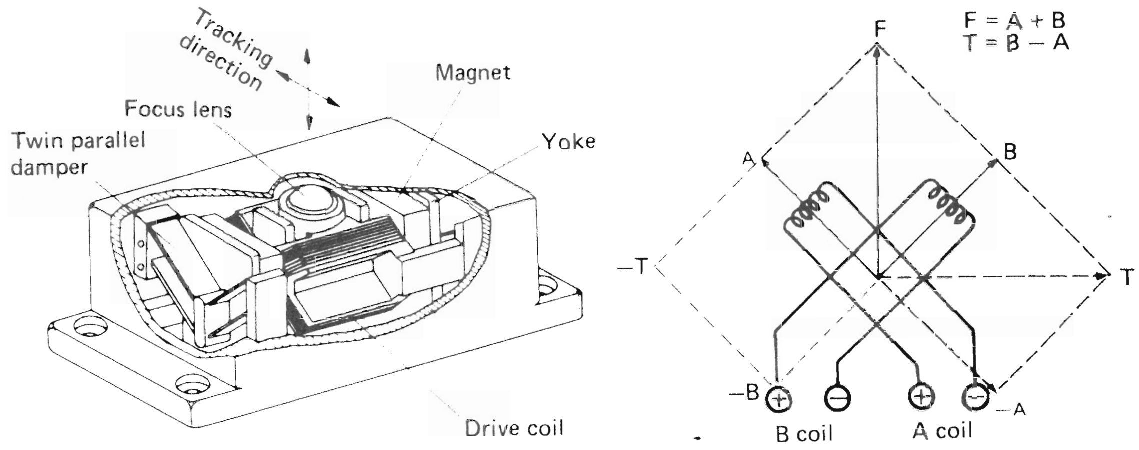


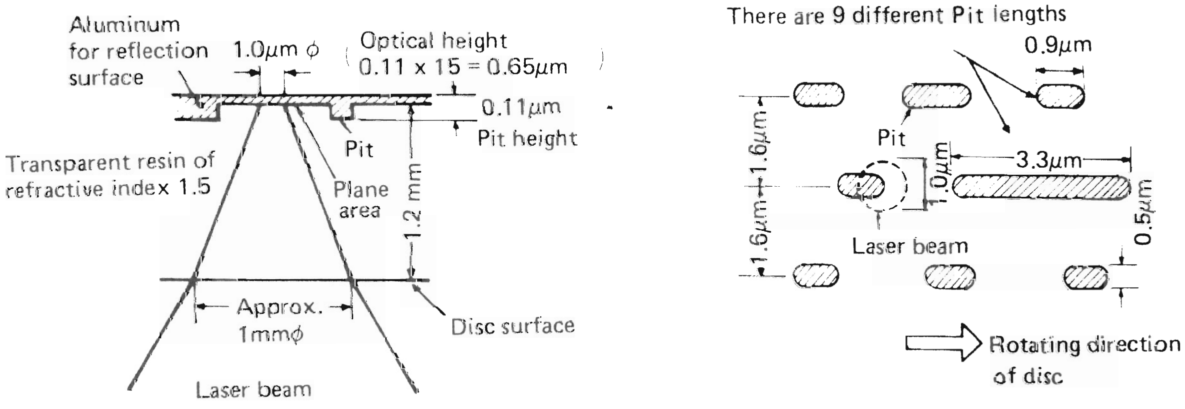
Fig. 27 Actuator assembly

8-5. Reading the Disc Information

Fig. 28 shows a cross sectional view of the disc and the laser beam.

When the laser beam hits the surface of the disc it is about 1mm in diameter. The transparent layer has a refractive index of 1.5 and is used as a lens to reduce the size of the beam to 1μm to focus on the pits.

The ratio of the areas of the 1mm spot on the surface compared to the 1μm spot on the pit area is 1,000,000 to 1. Therefore excessive dirt or scratches on the disc surface may affect the reading accuracy.

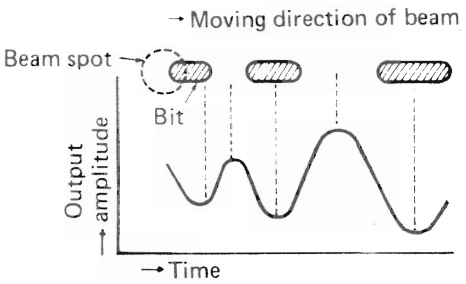

Aluminum for reflection surface
1.0μm ϕ
Optical height 0.11 x 15 = 0.65μm
0.11μm
Pit height
Pit
Transparent resin of refractive index 1.5
Plane area
1.2 mm
Approx. 1mmϕ
Disc surface
Laser beam
There are 9 different Pit lengths
0.9μm
1.6μm
1.6μm
Pit
1.0μm
3.3μm
0.5μm
Laser beam
Rotating direction of disc

Side view

Top view

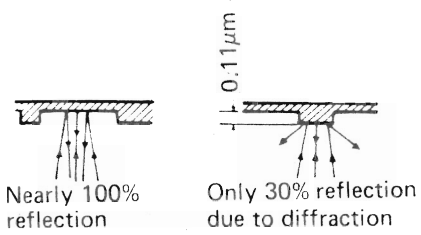
Fig. 28 Disc

The actual height of a pit is 0.11μm. Looking from outside the disc, through the polycarbonate layer (refractive index = 1.5), the perceived height is .165μm. this corresponds to about 1/4 wavelength. Therefore, the light is 180° out of phase (1/2 wavelength) with the light reflected from the non-pit area. Fig. 30 shows the relationship between the disc surface and the waveform generated.



(c) Pit & output signal

Fig. 30 Reflection from disc



(a) Plane area (b) Pit area

Fig. 29 Pit vs. output signal

When the beam hits the plane (non-pit) area, the light is reflected 100% and returns to the photo detector.

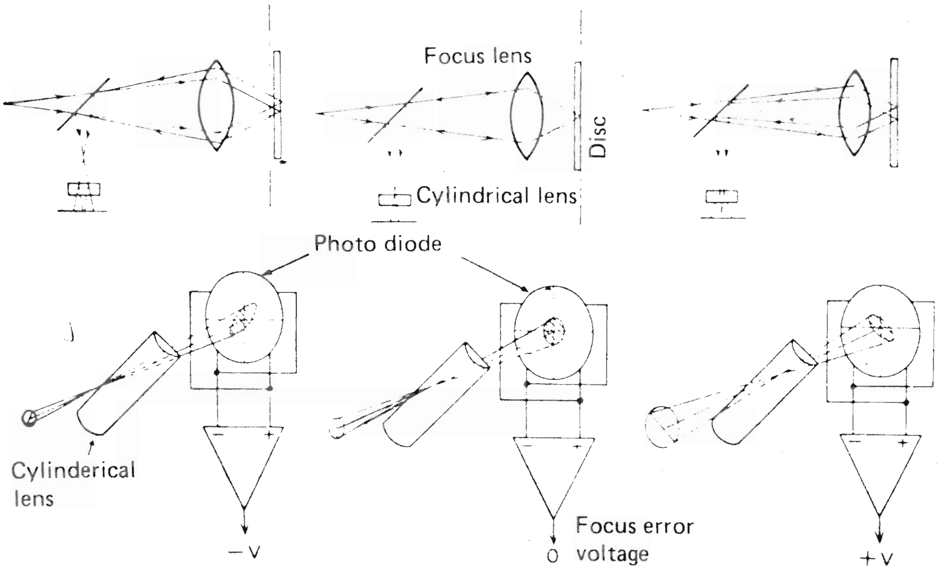
This waveform is actually a continuous analog waveform from the digital signal of 4.3218MHz (bits/sec.) recorded on the disc and is called an RF signal.

8-6. Servo Circuits

Focusing Servo

The laser must always be focused on the pit area. Since it is impossible to make a disc that has less than .11μm warp, (pit size) the focus lens must move up and down (following the disc) to maintain proper focusing.

[illegible]



(a) Disc is too far. (b) Focused to pit (c) Disc is too closed.

Fig. 31 Focusing conditions

They cylindrical lens affects the laser beam in such a way that if it is not focused properly it produces an eliptical shaped spot.
The spot falls on a 4 section photo detector.

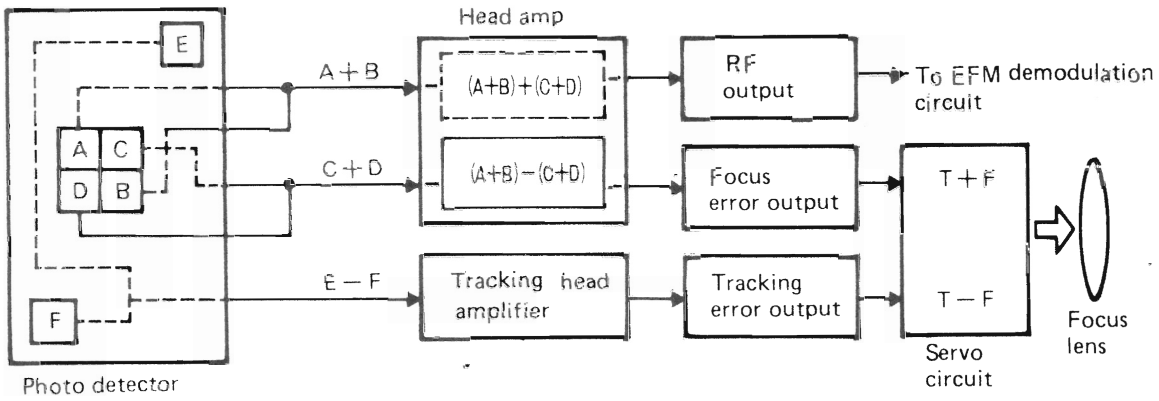


Fig. 32 Head amp circuit

↑ 3-beam tracking system

The voltage from opposite sections of the detector is added and subtracted from the other sections [(A + B) − (C + D)]. The result is a focus error voltage that is used to drive the focus lens to the correct focusing point.

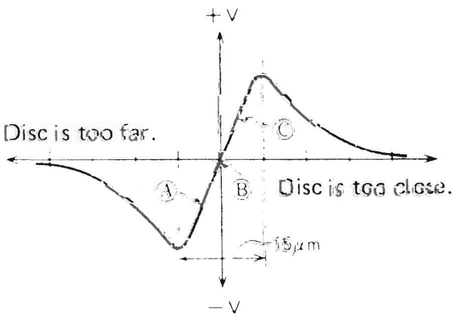


Fig. 33 Focus servo respones curve

Tracking Servo

The laser beam must follow the spiral path of the disc. Detection is made using a 3 beam system derived from the grating lens. The zero order beam is used for RF, and focus error detection. The two 1st order beams are used for tracking.

Fig. 34 illustrates the tracking conditions. The average reflections from the pit and non-pit area should be about equal. The voltage from each tracking photo detector is subtracted ($S_1 - S_2$). The result is an error output voltage (TE) that is used to move the focus lens to maintain proper tracking.

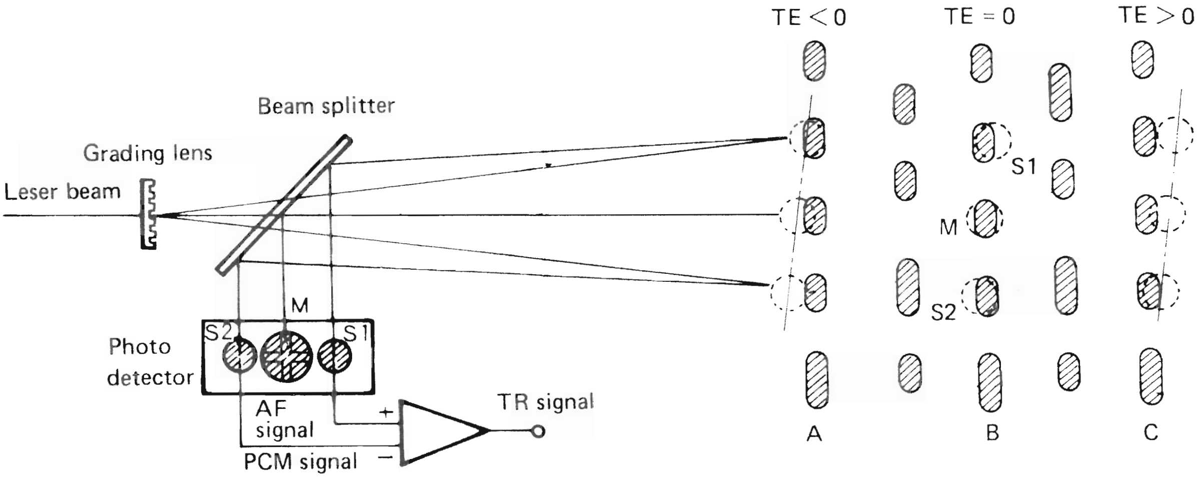


Fig. 34 Tracking conditions

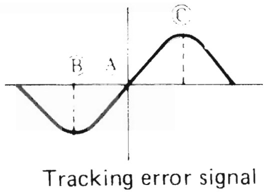


Fig. 35 Tracking servo response curve

Traverse Servo

The Focus lens has a lateral range of about ±40 tracks. To keep reading the tracks as the disc plays the focus lens assembly must be moved. This is done with a stepping motor which turns about 15° every 40 tracks, moving the assembly across the disc.

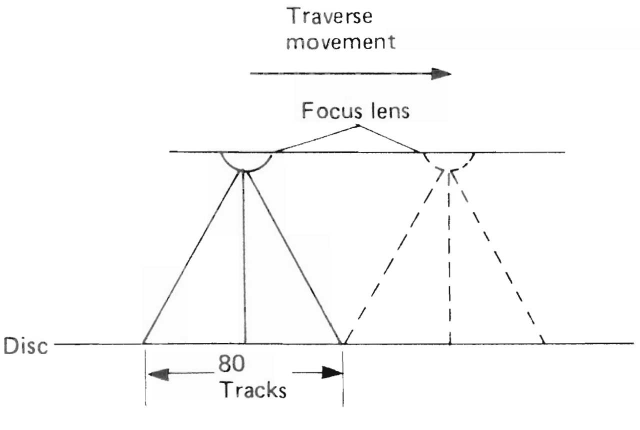


Fig. 36 Traverse assembly movement

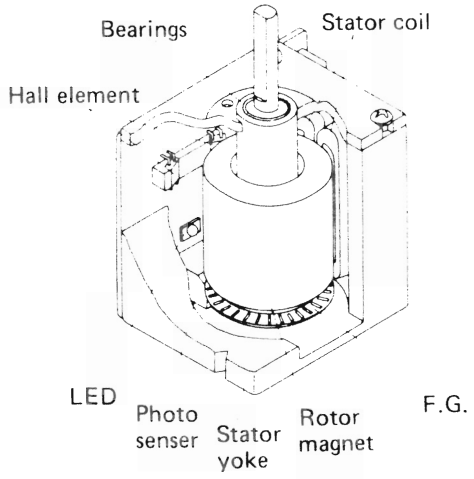


Fig. 37 Traverse motor cross section

CLV Servo

What is Linear Velocity?

The compact disc uses a constant linear velocity (CLV) drive system. This means that the disc speed changes to maintain a constant reading speed of approx 1.3m/s. In Fig. 38 the distance from A to B is shorter than from C to D. To read this data at a constant speed the disc must rotate slower at the outer periphery. The range is 200 ~ 500rpm from inner to outer periphery. The proper speed is maintained by reading the synchronizing signal (7.35kHz) and comparing it to a reference signal.

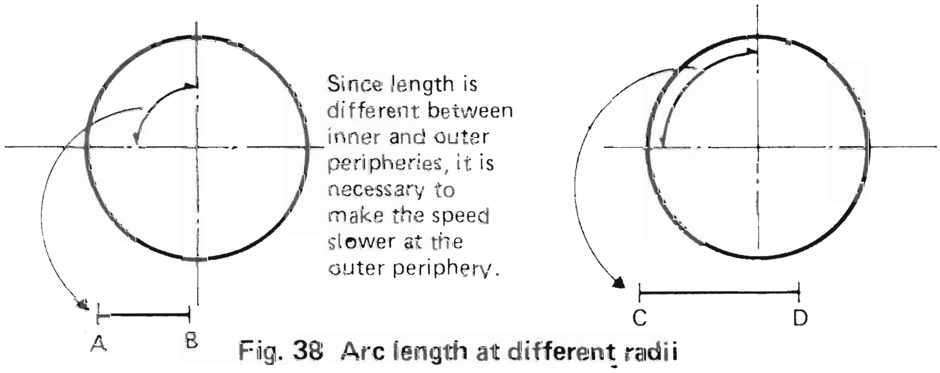

Since length is different between inner and outer peripheries, it is necessary to make the speed slower at the outer periphery.
A
B
C
D

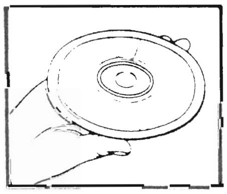
Fig. 38 Arc length at different radii

The Synchronizing signal at the beginning of each frame (7.35kHz) is detected and compared to a reference signal. Any deviation detected is sent to the motor drive to vary the speed of the spindle motor.

9. Handling Precautions

Only compact discs identified with the following mark can be used with this player.

COMPACT
disc
DIGITAL AUDIO



- Hold compact discs by the edges so that the surface is not soiled with fingerprints.

- Be careful not to scratch the surface with fingernails or other sharp objects, particularly when inserting and removing discs in their cases.
- Do not bend the disc.
- Do not use record cleaning sprays or static electricity prevention liquids.
- Do not wipe with benzene, thinner or any other solvent. If the surface is soiled, wipe gently with a soft, damp (water only) cloth.
- If the disc is brought from a cold environment into a warm room, dew may form on the disc. Wipe this off with a soft, dry cloth before using the disc.
- Do not write on the label with a ball-point pen, hard pencil or other hard writing utensil.
- Always remove the disc from the disc compartment when you have finished listening to it.

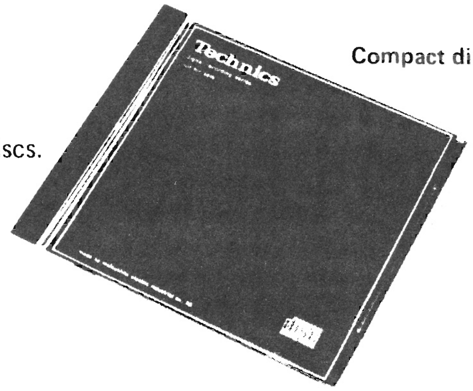
Storage Precautions

- Be sure to store discs in their cases to protect them from dust, scratches and warping.
- Do not place or store discs in the following places:
  1) Locations exposed to direct sunlight.
  2) Locations with high humidity or a lot of dust.
  3) Locations directly exposed to a heat outlet or heating appliance.
  4) In the glove compartment or rear ledge of an automobile.

Compact Disc Storage Case

Compact disc cases are standardized worldwide. The directions below on handling cases are the basic rules for all compact discs. Refer to the instructions packed with the disc for further directions.

Note:
Technics does not sell compact discs.



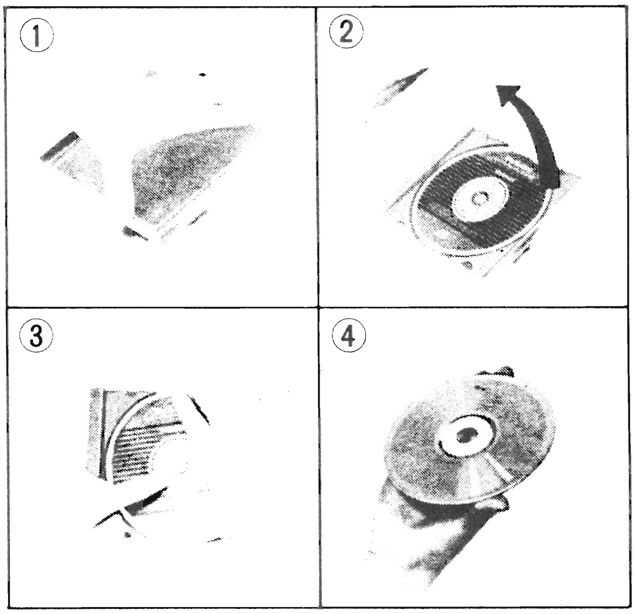
Removing a Disc

(1) Hold both sides of the bottom section with your right hand and the top section with your left hand.

(2) Open the top section as shown. (The disc should be stored with the label facing upward.)

(3) Press down on the spindle hole with left index finger and pick up the disc with your right hand.

(4) Shown here is the recorded information side (shiny silver surface) of the disc.



Replacing a Disc in Its Case

(1) Place the disc in the case so the spindle hole is over the holder.

(2) Press downward to firmly seat the disc in the case.

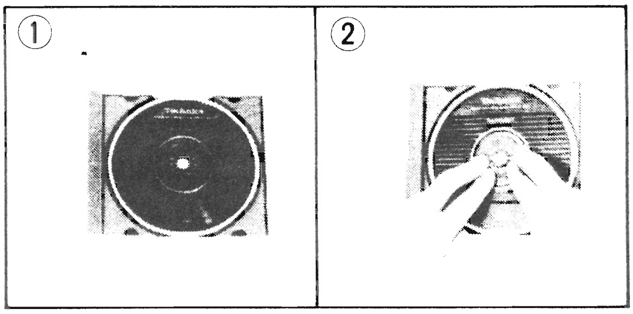


Fig. 39 **Handling compact discs**

The block diagram shows two basic sections of the player. The optical pick-up section is responsible for maintaining proper data read out. The signal processing section is responsible for connecting the digital signal from the pick-up back into an analog signal for listening.

Starting with the optical pick-up or data recovery section, the following is a breakdown of the functions of each optical component from the laser diode to the photo detector.

10. Adoitional Technical Information

The technical literature for the compact disc system and the SL-P10 is organized as follows:

1) Service Manual : Includes dissambly instructions, schematics board layout and parts list.
2) Technical Guide : Principles of the "Compact Disc System" includes general descriptions of the PCM process, disc format and optical systems.
3) Technical Guide : Vol. 1 "SL-P10 Circuit Descriptions" includes detailed description of the major circuits.
4) Technical Guide : Vol. 2 "SL-P10 Troubleshooting Guide" includes troubleshooting flow charts for all major circuits.
5) Technical Guide : Vol. 3 "SL-P10 Adjustment Manual" includes complete adjustment procedures.

Technics

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